Canadian Council of Ministers of the Environment

CCME

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Environmental Life Cycle of Packaging

IP-116

May 1990

92-00351/

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PREFACE

This report is one of a series prepared for the National Packaging Task Force in support of the development a national packaging policy for Canada. The complete series of reports is as follows, together with the companies that prepared them:

• Packaging Application in Canada;	MacLaren Engineers Inc.
• Packaging Reduction, Reuse and Recycling Technology Options;	MacLaren Engineers Inc.
• Stakeholder Positions and Response to the Development of the National Packaging Protocol;	MWR and Associates
• Household Consumers and Packaging;	Resource Systems Management International
• Legislative Initiatives Relating to Packaging and Implications for the National Packaging Protocol;	Resource Systems Management International
• Economic Considerations in the Development of the National Packaging Protocol;	The Coopers and Lybrand Consulting Group
• Environmental Life Cycle of Packaging;	VHB Research and Consulting
• Agenda for Action for the National Packaging Protocol;	Recycling Development Corporation

The key data and analyses of each of these reports are included in a further report titled The Technical Basis For The National Packaging Protocol: Summary Report prepared by MacLaren Engineers Inc. Input to all reports has been received by M. J. Ramsay and Associates.

The National Packaging Task Force is a multi-stakeholder task force comprised of representatives from federal, provincial and territorial governments, municipalities, industry, environmental groups and consumer groups. The goal of the task force has been to develop and recommend to the Canadian Council of Ministers of the Environment a national packaging

policy for Canada.

In March 1990, the Canadian Council of Ministers of the Environment adopted the national packaging policy that was recommended to it by the National Packaging Task Force. The policy takes the form of a National Packaging Protocol that has been agreed to by all members of the task force. The National Packaging Protocol is included in this series of documents as Appendix A of The Technical Basis For The National Packaging Protocol: Summary Report.

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1 Introduction and background

1.1 What is environmental life cycle analysis?

An environmental life cycle analysis is an assessment of the environmental effects over the entire life cycle of a product, from raw material extraction to final disposal. It enables an assessment of the total environmental effects attributable to a product.

The need for environmental life cycle analyses emerges from inadequacies of the economic market system. The major inadequacy is the failure to capture the full value of environmental effects within the market. Thus, for example, erosion and habitat disruption during raw material extraction to create a package may create certain environmental effects, the value of which is not assigned directly to the extracted resource, and thus the costs of these environmental effects are not passed on to the manufacturer using these raw materials. As part of the manufacturing process, the manufacturer may produce air emissions which lead to environmental effects, the costs of which may not be fully borne by the manufacturer, and which are therefore not passed along in the manufacturer's sale price for the package. Finally, the consumer of the product may ultimately dispose of the package. This disposal incurs certain economic and environmental costs, but these too are not directly assigned to the package which is being disposed. Consequently, at no stage in the process does anyone have the information necessary to choose an alternative package which would reduce environmental effects.

The purpose of the environmental life cycle analysis is to consolidate the information about environmental effects so that decision makers are able to choose packaging types or systems which minimize adverse impacts on the environment.

1.2 How is environmental life cycle analysis relevant to the National Packaging Protocol

The National Packaging Protocol is designed to help achieve diversion of waste from waste disposal facilities by means of reduction, reuse and recycling. The reasons for doing this include to reduce environmental effects associated with packaging manufacture, distribution, and disposal.[1] Unfortunately, because information about environmental effects are not carried with products or materials, what appears to be the product or material best able to achieve the diversion from landfill may or may not be the product or material which minimizes environmental effects over its life. It is important to ensure that reductions in waste going to landfill are not achieved at the expense of increases in upstream environmental effects which exceed the reductions in impacts of waste disposal.

The reduction, reuse and recycling sequence, which is meant to assign priorities to activities on a scale of increasing environmental preference—reduce, reuse, recycle—is only a rough guide. In particular instances, even if an improved infrastructure could be established, it may be better to recycle than reuse and reuse rather than reduce, or even to recycle rather than reduce. Only analysis will reveal the environmental consequences.

1.3 Where should an environmental life cycle analysis begin and end?

Decisions must be made about what environmental effects to consider, and how far to carry considerations of environmental effects. If considering the environmental effects of glass bottles, for example, should one consider the environmental effects of equipment used to extract sand? Of manufacturing the equipment used in the sand pits? Of the construction of the factory to make the earth-moving equipment?

There is no technical answer to the question of where to truncate the analysis, but obviously there is little merit in extending the analysis into impacts of smaller and smaller magnitude, particularly where these incremental effects are outside the precision of the estimates of major impacts. For example, if the carbon dioxide emissions from aluminum manufacturing are accurate within 1 kg, then there is little point in getting a lot of information on sources of CO_2 measured in milligrams.[2]

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1 In Phase 1, the stakeholders agreed that "environmental protection was the underlying principle of the NAPP." (MacLaren,1989:6-10).

2 However, the magnitude of all emissions should not arbitrarily be truncated at some specific unit of measure, since a very small quantity of an extremely toxic emission may worthy of more detailed scrutiny.

In addition to the question of how far back to trace impacts is the question of the types of impacts to consider. Again, there is no technical answer, but the types of environmental effects to address is considered in the next chapter.

2 Types of environmental impacts

The packaging system requires resources (inputs) and produces emissions (outputs) which have environmental impacts. These are summarized in Table 1.

Table 1
Resources, emissions and impacts of packaging systems.

Resources	Emissions	Areas of impacts
Energy	Gases	Human health
Materials	Liquids	Social well-being
Land	Solids and sludges	Terrestrial ecosystems
Air	Noise and vibration	Aquatic ecosystems
Water		Global climate
Labour		Future resource availability

2.1 Impacts of concern

The specific impacts that result or may result from packaging will depend on a wide variety of site specific circumstances, and, where there is local variation, cannot be the basis on which decisions are made about using one packaging material rather than another, or using one package design rather than another. However, consideration of the areas of impact is useful for identifying the specific types of resources and emissions to be addressed. For example, it is (at least partly) because of concerns about future resource availability that there

is concern about timber harvesting for paper production; it is (at least partly) the result of human health considerations that there is concern about emissions from incinerators, or leachate from landfills. These environmental impacts, in turn, will need to be balanced against other types of impacts, such as economic impacts.

2.1.1 Human health

The primary human health consideration concerns the exposure to contaminants during the package production, use, or waste management. During package production and disposal, solid, liquid or gaseous releases of potentially toxic compounds may occur. Possible substances of concern include:

- *metals*—aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, molybdenum, nickel, selenium, silver, sodium, tin, vanadium and zinc.

- *acids and acid gases*—hydrogen chloride, sulphur oxides, hydrogen chloride, hydrogen bromide, hydrogen sulphide, and nitrogen oxides.

- *chlorinated organics*—chlorobenzenes, chlorophenols, chlorinated alkanes (e.g. dichloroethane), di– tri– and tetra–chloroethylene, methylene chloride, polychlorinated biphenyls, polychlorinated dibenzofurans, polychlorinated dibenzo-p-dioxins, and trichloroethylene.

- *other organics*—benzene, cresoles, mercaptans, phenols, polycyclic aromatic hydrocarbons, and toluene, xylene.

In addition, a major criterion in the selection of materials to be used in packaging for some products, i.e. foods and beverages, is that the packages do not permit contaminants, like those identified above, to enter into foods and beverages where they may lead to human health effects.[3]

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3 For example, concern has been expressed by some that certain heat-susceptor packages used for microwave cooking may result in small amounts of chemicals, including benzene, leaking into food (Strauss, 1990).

2.1.2 Social well-being

Packaging production and management may cause other impacts on our overall quality of life. These other impacts include noise and vibration from manufacturing, transportation and disposal facilities, disruption of recreational areas through displacement or contamination, and nuisance impacts such as odours and litter.

2.1.3 Impacts on ecosystems

Packaging may have impacts on terrestrial or aquatic ecosystems as a result of contamination or physical or chemical destruction of habitats. Again these impacts can only be assessed directly on a site specific basis, but the existence of potential for these impacts is indicated by emissions of contaminants to air, or water, and resource input requirements, particularly of land and water. Packaging systems more likely to end up as litter also may impact on ecosystems.

2.1.4 Global climate

There are three major influences on climate receiving widespread attention: deforestation, depletion of the ozone layer, and global warming. Packaging systems dependent on forest products or leading to releases of greenhouses gases (e.g. CO_2, CH_4) or ozone depleting gases (e.g. CFCs) may be making a contribution to global climate change.

2.1.5 Future resource availability

Finally, packaging uses resources. Where these resources are non-renewable (e.g. fossil fuels, metals), or are mismanaged renewable resources (e.g. mismanaged forests), use of these resources in packaging may decrease the future availability of resources and the quality of life. Similarly, the package design may determine the overall life cycle of the package, and therefore its resource requirements, i.e. is the package designed for recycling into the same type of package, a lower quality use, or does the package design preclude recycling.

2.2 Comparing impacts of different types

A wide variety of effects of packaging or packaging systems are discussed above. In order to choose one packaging material over another, or one package design over another, it is necessary to integrate impacts of different types and to come to a conclusion about which material or design is "best" from an environmental perspective. This decision is complicated by the fact that almost certainly one will be better for some criteria and worse for other criteria; a paper package may be manufactured from a renewable resource, but may produce a

greater mass of waste than a plastic package, and may be more prone to ending up as litter than would a returnable glass bottle.

In determining which is "best", two types of issues must be addressed: technical issues, and questions of value.

Technical issues

The evaluation of impacts has a technical component. The preferred alternative for any given impact will be determined on the basis of the technical evaluation of that impact. Which of two alternatives is preferred may be very sensitive to some of the input data, and these input data may be uncertain, or highly site-specific. For example, a comparison of refillable and non-refillable glass bottles is likely to be very sensitive to the number of return trips the bottle takes. The results of the evaluation may be very different if the number of return trips is 2 or 3 than if it is 10 or 20. As part of the technical evaluation, care must be taken to identify those components of the evaluation to which the final result is very sensitive and to ensure that the assessment of those components is done carefully.

Questions of value

Even if all interested parties could agree on all technical issues, the problem of comparing air emissions to natural resource use remains. Ultimately, these comparisons are questions of value and cannot be decided on the basis of a technical evaluation. If the analysis is to be broadly accepted and useful to decision making, then the relative values of various types of impacts must be broadly accepted, or have been determined through a credible process.

3 Life cycle of major packaging materials

3.1 Generic product life cycle

Although each product will have a unique process that takes it from raw materials in the ground to waste requiring disposal, there is a high level commonality which can assist thinking about life cycle effects, and the way in which reduction, reuse and recycling fit within the life cycle framework. This generic sequence of steps is illustrated in Figure 1.

3.2 Example analyses

An environmental life cycle analysis consists of the following:

- identification of each process involved in the production, use, recycling and disposal of the material
- documentation of the inputs (energy, raw materials) and outputs (solid wastes, air emissions, water effluent) observed in each process
- analysis of the results.

The following sections elaborate on these items, citing examples from the literature.

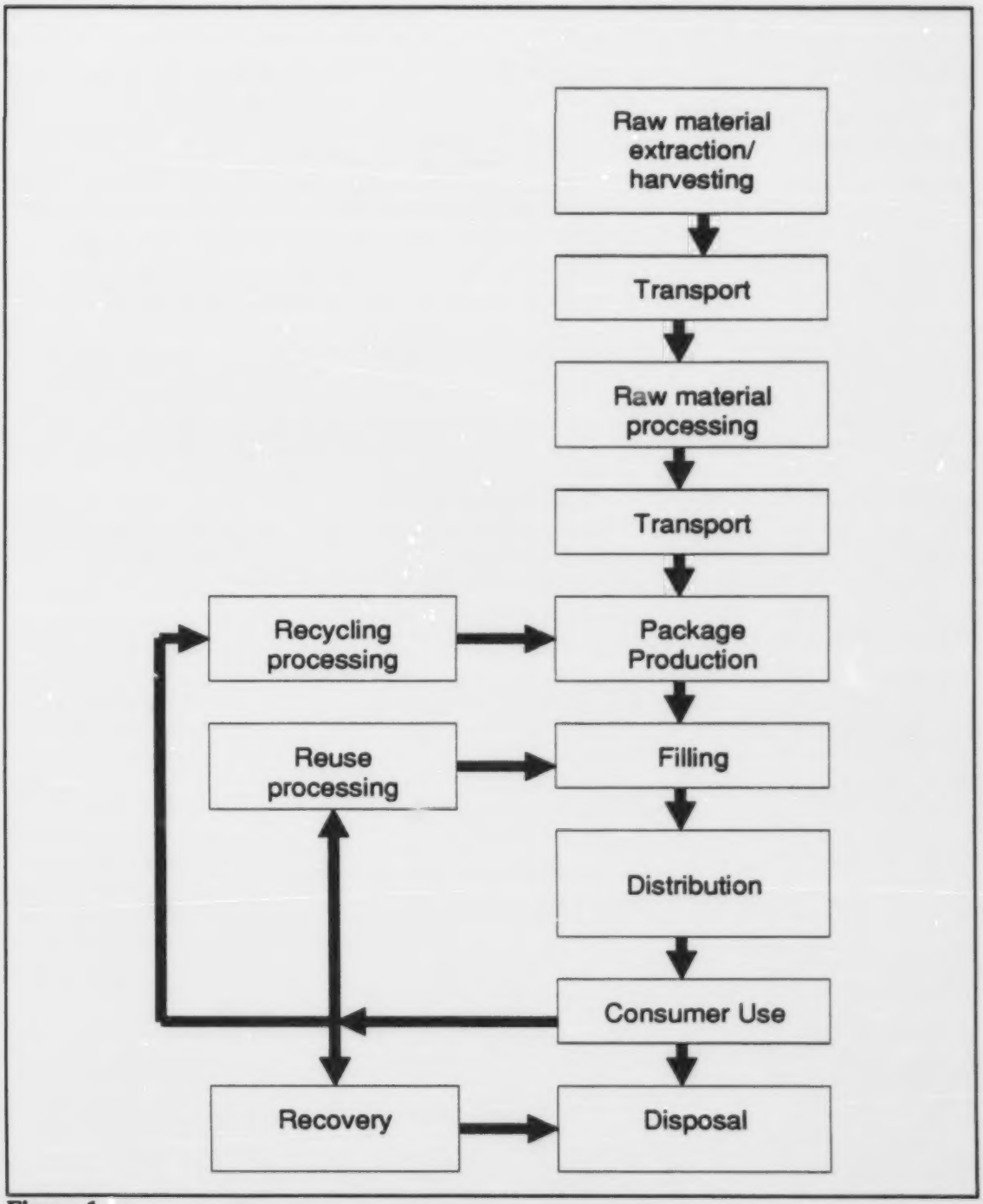

Figure 1
Generic sequence of steps in package production, use and disposal

3.2.1 Identification of processes

Each process in the manufacture and disposal of a packaging material must be identified.

The flowcharts in Figure 2, Figure 3, Figure 4, and Figure 5 show the basic processes in the manufacture and disposal of glass, steel, aluminum, and corrugated cardboard packaging respectively. The arrows indicate that transportation is usually required between the processes. (The impacts of transportation must also be addressed.)

Often there is more than one disposal option available, for example landfill, EFW, or recovery for recycling. All options and their environmental impacts must be considered so that the disposal option best suited to meeting the objectives can be selected.

3.2.2 Documentation of inputs

Inputs and outputs of each process must be monitored and documented. The enlargement of detail in Figure 2 presents the resources and wastes involved in the manufacture of soda ash for glass production. The tables in Appendix A give an example of the inputs and outputs monitored by MRI for each stage in the manufacture and disposal of steel soft drink cans.

These tables are indicative of the type of analysis that is required, but are not comprehensive or conclusive. Energy use disaggregated by fuel type might also be included in a chart such as this. The contaminants listed in Chapter 2 of this report should be considered as well.

3.2.3 Analysis of the results

The literature shows that no material will rank first in all impact categories. For example, in a study done by MRI aluminum cans are shown to produce the least post-consumer solid waste of all container systems considered(see Table 3). However the production of aluminum also uses the most energy, releases the largest amount of waterborne emissions, and produces large quantities of industrial solid waste and atmospheric emissions relative to the other systems (Hunt; Welch, 1974). The objectives for minimizing environmental impacts must be precisely defined before the various impacts from the production of each material can be evaluated; a narrow focus on the mass of post-consumer solid waste will ignore other environmental effects which may be quite significant.

Once the objectives are defined a weighting scheme may be used to amplify the impacts of particular concern. In a study done by MRI for the Society of the Plastics Industry Inc. the

following weighting scheme was used to reflect the association's concern with energy use (Hunt, 1974).

Type of impact	Relative weight
Energy	x0.4
Atmospheric emissions	x0.2
Waterborne wastes	x0.2
Raw materials	x0.05
Water consumption	x0.05
Industrial solid wastes	x0.05
Post-consumer solid wastes	x0.05

To highlight emissions which are particularly toxic it might be preferable to weight individual pollutants. Material inputs which are scarce may also be given a higher weight.

The analysis should include comparison of materials at different recycling and reuse rates. As an example of this, Figure 7 plots the recycling rate against the energy used in the production of soft drink container systems (Hunt, 1974). Figure 6 shows the change in energy used as the return rate of refillable containers increases (Hunt, 1974). (This figure assumes that no recycling is occurring.) At an 80% recycling rate, aluminum, steel, and plastic containers use less energy than glass containers refilled five times. However when there is no recycling occurring, glass bottles use less energy when they are reused three or more times. Given the extreme sensitivity of the conclusions, locally relevant rates, whether actual or planned, need to be used. Analysis of recycling and reuse data is quite complex and a computerized model may be required to assess the environmental effects of combinations of materials and systems in different circumstances.

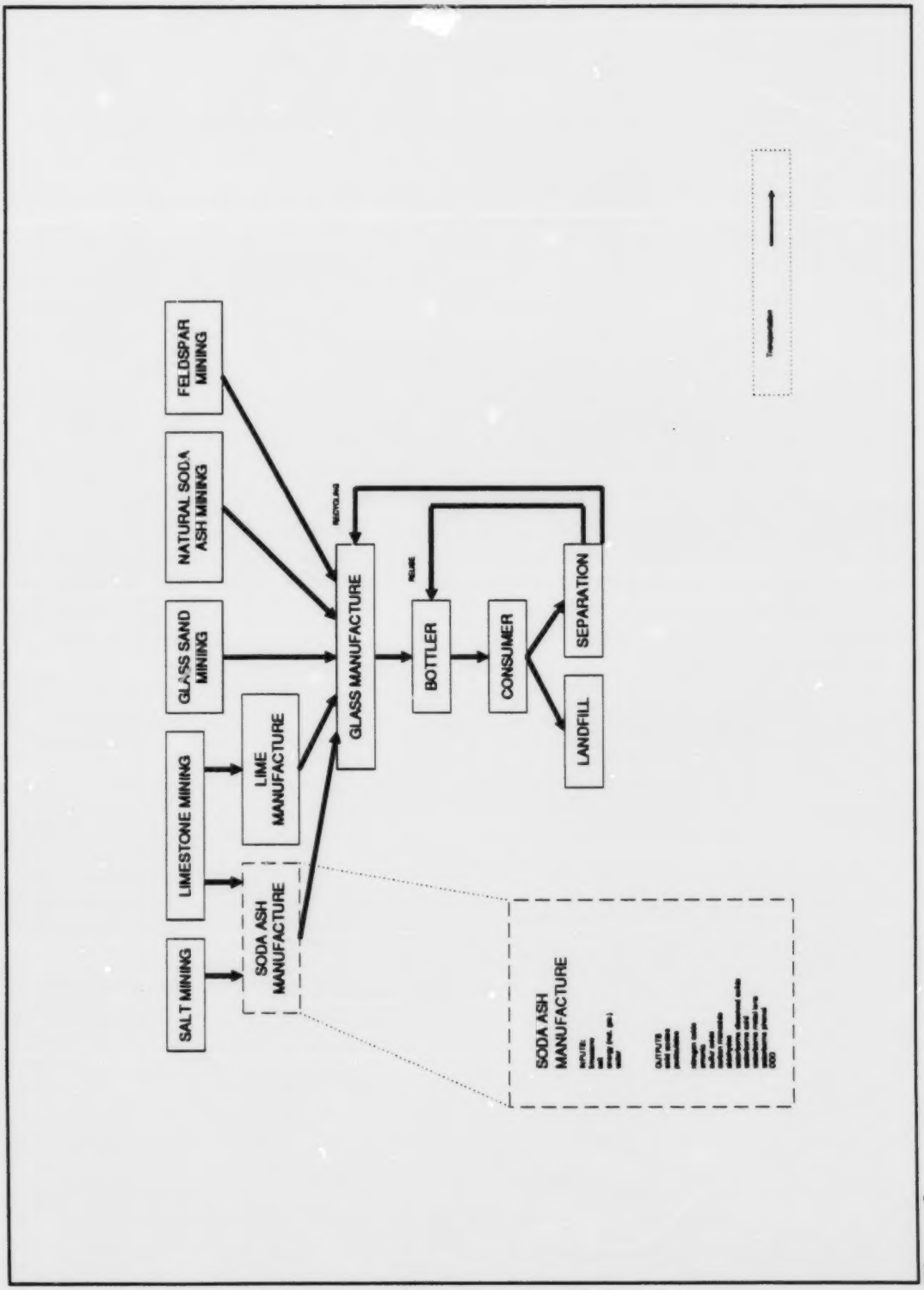

Figure 2
Production and Disposal of Glass Packaging

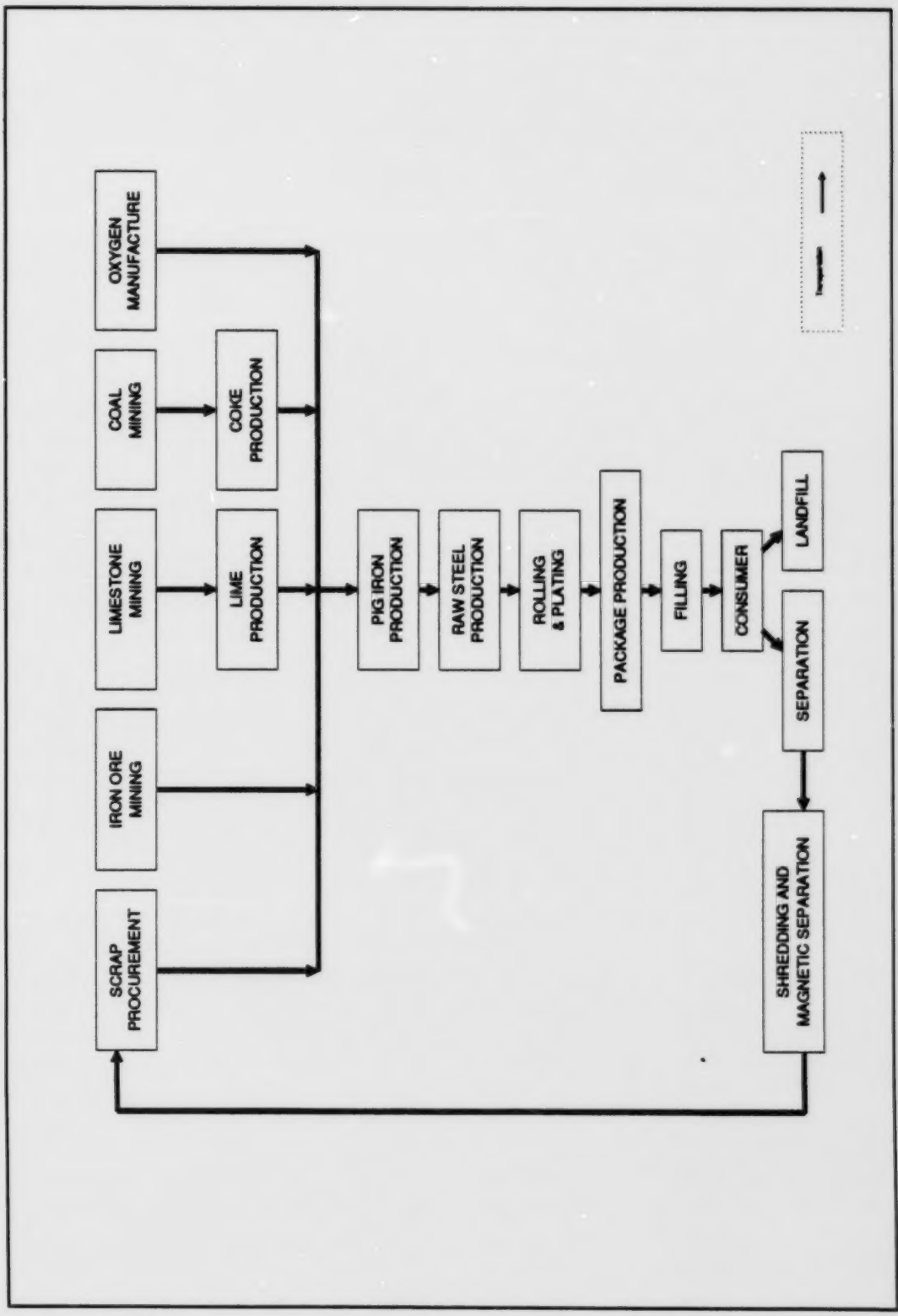

Figure 3
Production and Disposal of Steel Packaging

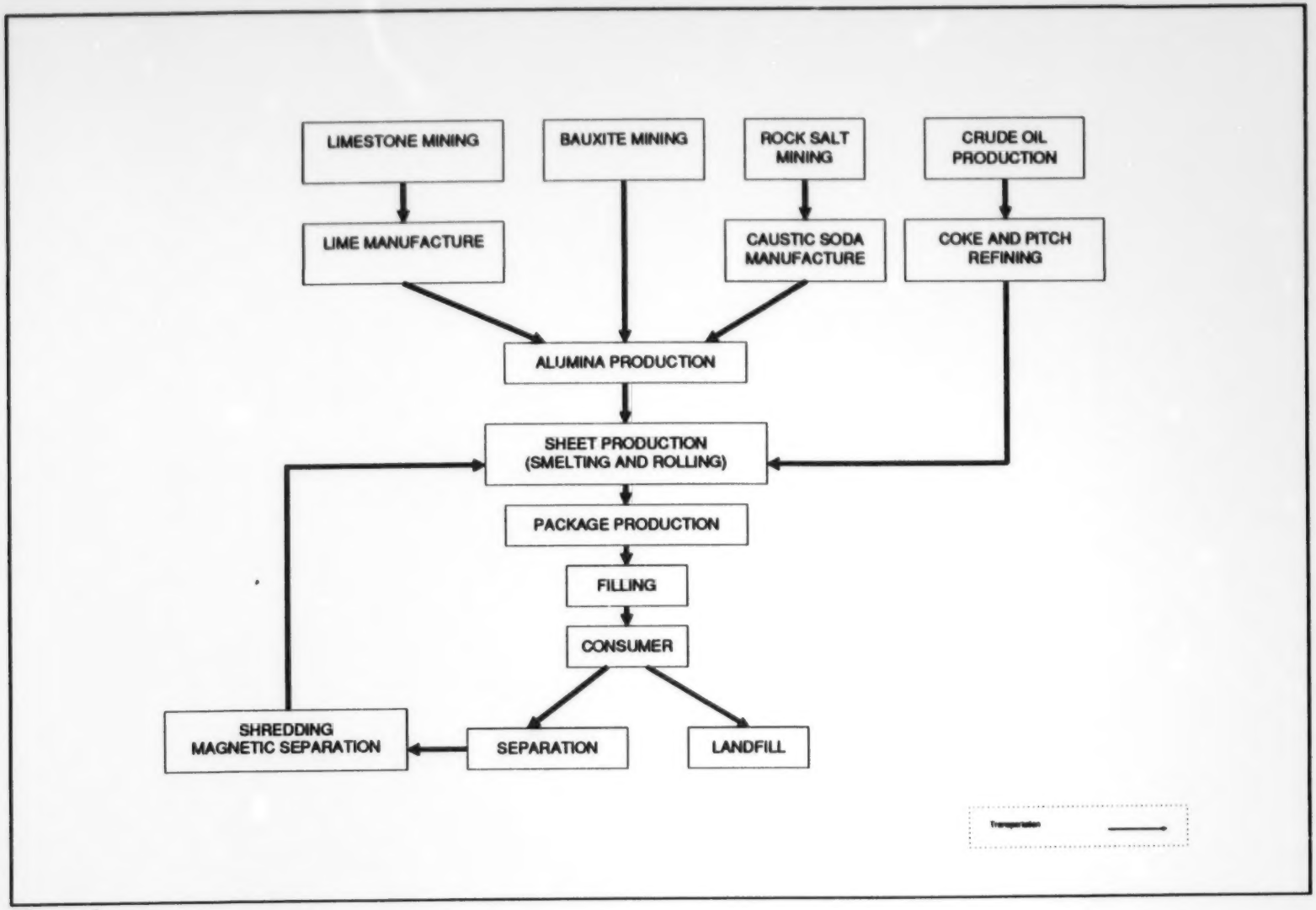

Figure 4
Production and Disposal of Aluminum Packaging

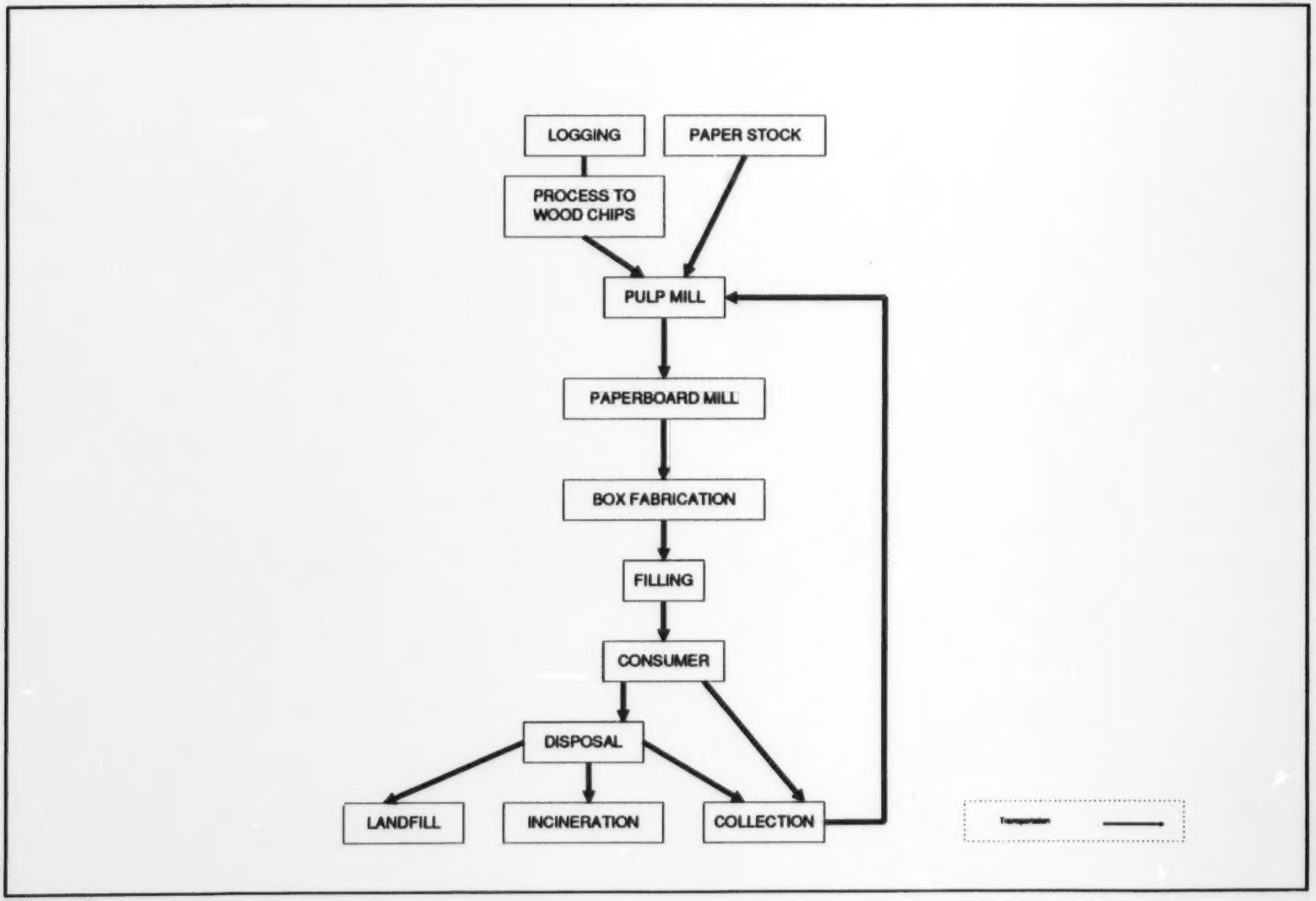

Figure 5
Production and Disposal of Corrugated Board Packaging

Table 3
Summary of environmental impacts for the production and disposal of packaging required for 1,000 L of soft drink product [1]

Impact	Units	Glass bottle returned 15 times	ABS Plastic	All steel can	Plastic coated glass	Steel can with aluminum closure	One way glass	Aluminum can
Raw materials	kg	47487	26453	115735	316031	116769	383197	84442
Energy	GJ	1563	5770	3771	6205	5265	6991	7371
Water	m^3	3801	11326	13847	10118	12102	11262	5364
Industrial solid wastes	m^3	20	17	287	89	247	106	96
Atmospheric emissions	kg	2911	9344	6293	10600	9528	11929	13837
Waterborne wastes	kg	1141	2229	772	1797	1462	1965	2513
Post-consumer solid wastes	m^3	23	57	9	99	9	97	7

Source: Hunt, Franklin, *et al*, 1974.

1 All packages with the exception of the returnable glass bottle hold 12 U.S. fluid ounces of liquid; the returnable glass bottle contains 16 U.S. fluid ounces of liquid.

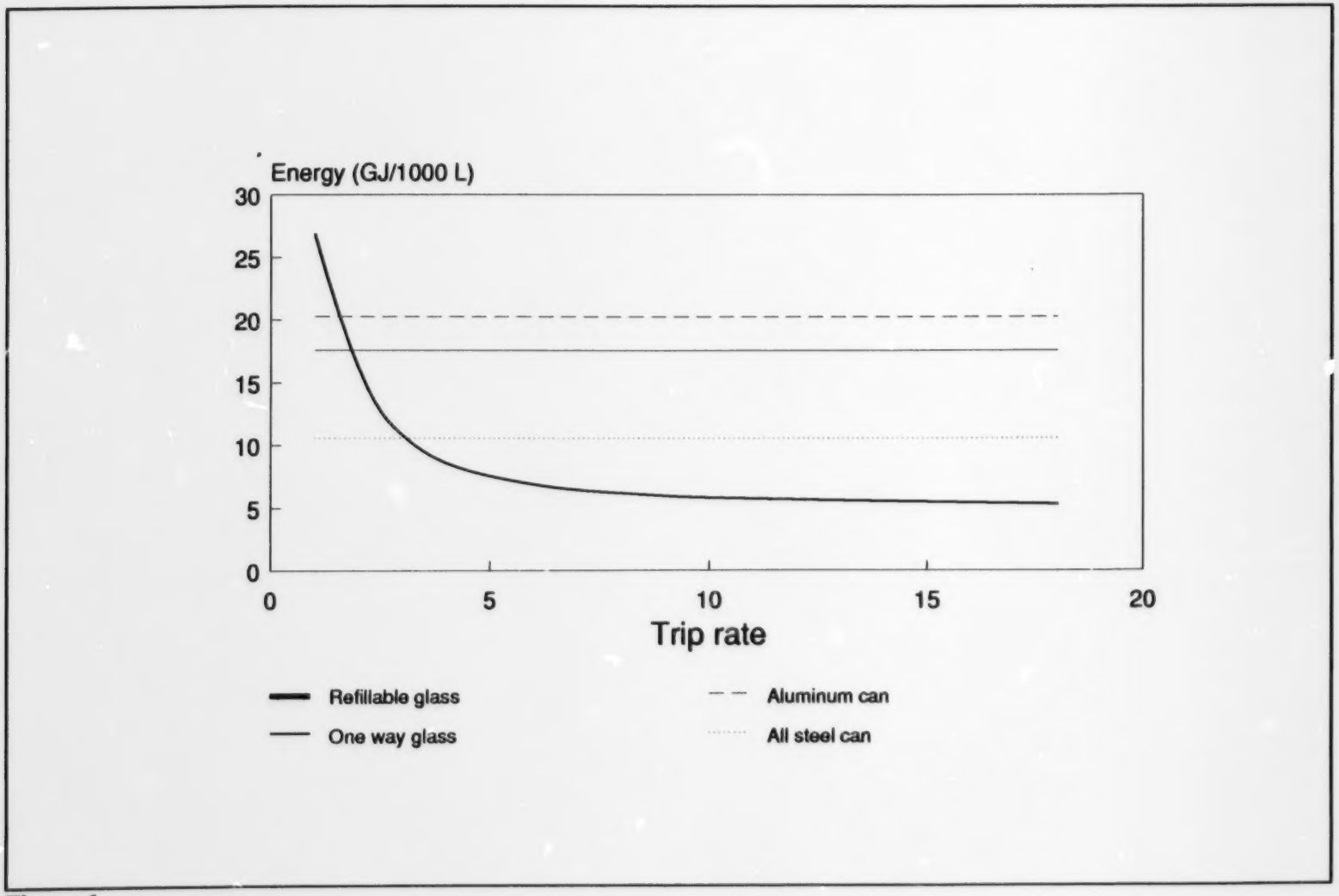

Figure 6
The effect of the number of return trips on energy use for soft drink packaging
(Hunt, Franklin *et al*, 1974)

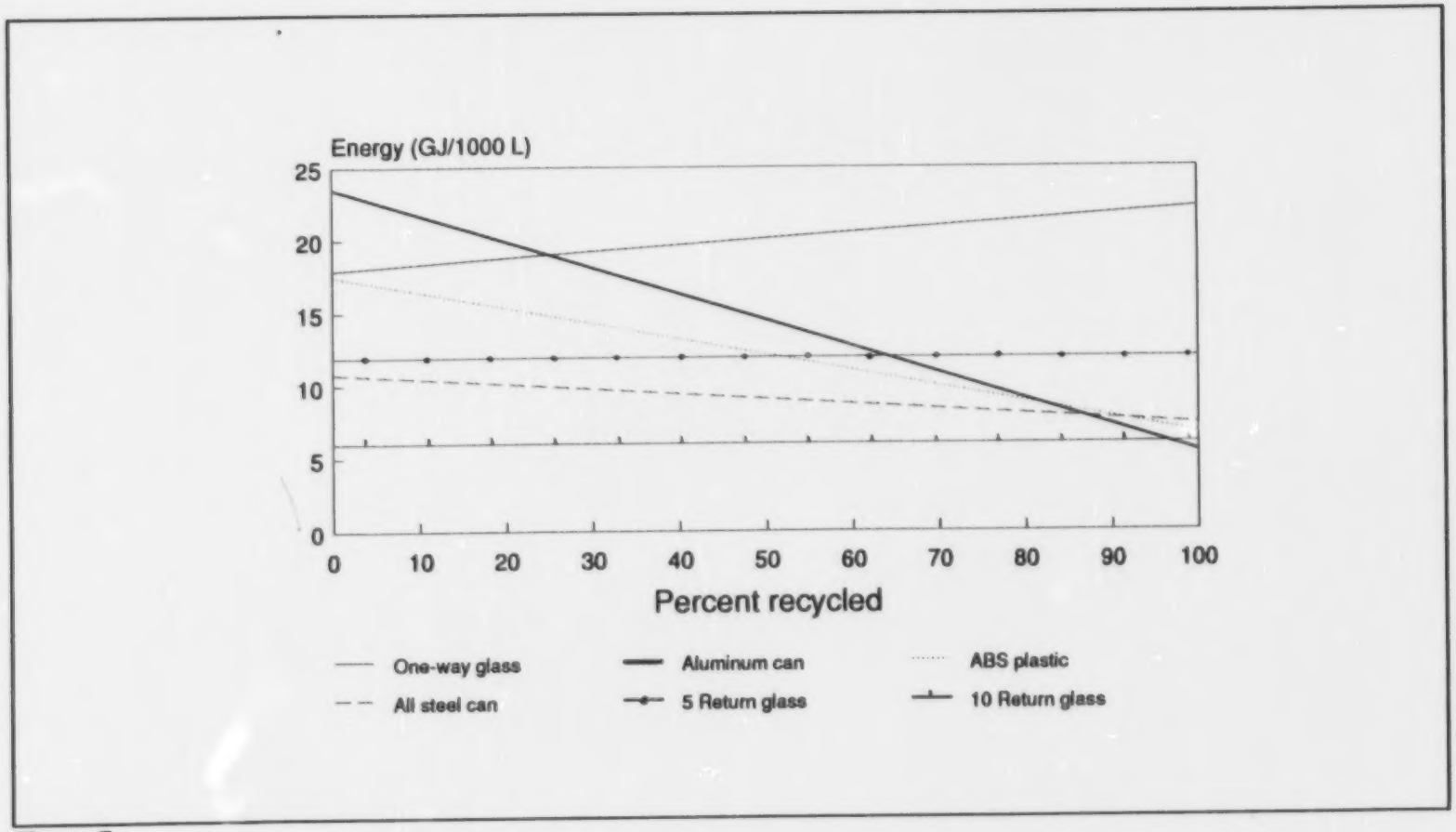

Figure 7
The effect of recycled content on energy required for soft drink packaging
(Hunt, Franklin *et al*,1974)

4 Historical work on environmental life cycle analysis

Comparative analyses of the environmental impacts of packaging materials were first undertaken in response to the sudden concern over energy resources during the Arab oil embargo of 1973. A number of packaging studies were commissioned by the United States Environmental Protection Agency at that time, focusing on the energy required to produce and deliver products in packages made of different packaging materials. With recent concern for environmental degradation, in particular problems in siting landfills near population centres, a new wave of studies has appeared (e.g. Franklin Associates, 1981; Lundholm & Sundstrom, 1985). Most of these studies have been commissioned by plastics associations in response to anticipated regulation which might restrict the sale of their product. Unlike the studies done in the 1970s the recent studies include not only a comparison of the impacts resulting from the production of packages but also analyses of the impacts of the various disposal options, including recycling, energy recovery and landfilling.

A computerized and manual literature search identified relevant material. The literature review showed that most of the life cycle analyses have been designed by a small number of research and consulting companies. These companies were contacted and researchers involved in life-cycle analysis studies were consulted to identify recent and on-going studies. Appendix B contains summaries of the major life cycle analysis studies.

The objective of most of the reviewed studies was not the comparison of container materials but rather a comparison of container systems. For example a material analysis of glass bottles would show the impacts resulting from the production of 1 t of glass; a system analysis would show the impact resulting from the packaging of 1000 L of soft drinks in glass containers, including the impacts from the production and disposal of carrier packages, transportation to the retail outlets, and transport from the outlet should the bottles be

refillable. Though looking at the entire delivery system is necessary when choosing the best waste management option, the containers chosen for the studies are not necessarily the ones used in Canada.

Not all of the commonly used packaging materials have been covered in the literature. Most of the studies thus far have focused on packaging for liquids such as soft drinks or beer. These include refillable and non refillable glass bottles, steel and aluminum cans. The Tetra Pak company has published a study comparing Tetra Brik composite packages to glass bottles (Lundholm & Sundstrom, 1985). A number of plastic resins have been studied, however the resin currently in use for the packaging of liquids, PET, has only been covered in one study. Although a few of the bottle studies include some analysis of the corrugated cardboard packages required to carry the bottles or cans, no study compares different types of paper packaging materials. There is certainly a void in the literature with respect to the other types of plastic packaging materials, styrene, wood, kraft paper and paperboard packaging.

Unfortunately, data from the previous studies have limited usefulness for reaching preliminary conclusions on the environmental life cycle impact of each packaging material. This is due to the limited range of packaging systems addressed as well as the assumptions made in each study. Some of these assumptions and their implications are described below with examples from the literature. They highlight aspects of the scope and methodology which must be considered before an environmental life cycle analysis can be undertaken.

4.1 Scope and methodology considerations

Applicability of the container systems reviewed to the Canadian consumer

Since most of the studies were done outside Canada the container size, packaging mode, and process characteristics are often not directly relevant to the Canadian situation. For example, ABS soft drink containers are no longer used in Canada, Canada uses Metric packages and Canada has a different electricity generation mix than the United States, Germany or Sweden. This could be accommodated if details of the calculations and analyses were given or obtainable, however this is often not the case.

Where the mass of the containers studied is available it is possible to calculate the impacts on a unit basis. The impacts documented in the various studies were compared for each material. The comparisons rendered large variations in both energy use and emissions across the studies. Discrepancies could be traced to assumptions concerning the transportation of packaging, secondary materials content, the type and range of impacts to be monitored, and the weighting of the data. These assumptions are discussed in the following sections.

An useable and useful methodology should make these assumptions explicit, and should be capable of testing their importance to the conclusions reached.

Transportation

The mode of transportation as well as the distance between process sites varies across the studies. To enable comparison among the studies impacts pertaining to transportation should be shown in units per distance travelled, for example $kg \cdot t^{-1} \cdot km^{-1}$.

Geographical boundary of the study

In order to circumvent the problem of varying distances some studies assumed a geographical system boundary in which only the effects occurring within the boundary are accounted for (Brown *et al*, 1976). For example, if the system boundary is Ontario, and ore is procured outside of Ontario, the energy required to extract the ore and transport it to Ontario for refining is not included in the energy analysis.

Location also affects the accounting of contaminant emissions. All of the studies reviewed showed water and airborne emissions with the use of pollution control equipment. Since pollution control regulations vary with jurisdiction, outputs between plants producing different materials may not be comparable if different pollution control standards apply to the plants.

The location of the production plant is also an important factor in the selection of the type of fuel(s) to be used in the combustion processes. For example, hydro power will be used to generate electricity if there is a suitable site close to the plant; otherwise fossil fuel generators will be used. The environmental impacts of electricity generated from each of these fuel sources are very different, both in composition and quantity.

It is preferable to consider effects wherever they may occur, but to indicate how the impacts are distributed.

Degree of recycling

The relative proportion of material recycled affects the amount of solid waste going to the landfill as well as the raw materials and energy required to produce additional packaging. A number of studies assumed the use of secondary materials (e.g. Franklin Associates, 1981; Lundholm & Sundstrom, 1985; Sellers & Sellers, 1989), however the proportion of secondary materials included in the final product varied across the studies.

Given the wide range of circumstances in Canada, the variation in the recycling level across the country may well suggest region specific assessments, targets, and strategies.

Allocation of organic materials

Organic materials such as wood, oil and gas feedstocks can be categorized as either an energy input or a raw material input to the packaging system. The argument for including raw materials as an energy resource is that there is a loss of potential energy that occurs as organic materials undergo processing. The argument against showing organic raw materials as an energy resource is that finished product made of organic materials are potential fuel even after they have been used and discarded; where dealing with complex molecules, post-consumer materials may be more valuable as a material than as a fuel. In either case, care must be taken to ensure that accounting is comprehensive, but double counting is avoided. Both approaches were used in the studies reviewed.

In general, organic materials are likely to be more valuable as *materials* than as *energy*, and how they are treated needs to be explicitly stated.

Currency of Data

The composition of packaging materials and the processes involved in their manufacture are continually changing. Packages have become lighter and use less raw materials in their production. Production technology is more efficient, requiring less energy per unit output.

The composition of the materials and plant efficiency varied amongst the studies. Without a consistent time frame the impacts resulting from the production of different materials or container types cannot be accurately compared.

Up-to-date assessments of the Canadian situation will need to be undertaken, and a mechanism for ensuring that they stay current needs to be integrated into the methodology for these assessments.

Inclusion of non-process energy use

Non-process energy is the energy required to extract, process and transport fuels used in the system. Non-process energy includes energy required to heat buildings and to maintain machinery. Industry data often do not differentiate between process energy and non-process energy. Some studies included non-process energy in their energy profiles of the packaging systems, and others did not.

To identify total environmental effects, both types of energy use need to be considered, however, they should be reported separately since different opportunities for savings will apply to each.

Disaggregation of water emissions, air emissions, and industrial solid wastes into individual pollutants

Most studies documented these wastes in kilograms per unit output. However the constituents of these wastes, which vary greatly in terms of toxicity and environmental effects, were often not listed. The contaminants considered in each study must be known before comparisons between studies can be made.

Because of these differences in toxicity, availability and other environmental effects, disaggregation by contaminant is required.

Inclusion of heat recovery in energy calculations

Some studies included the energy gained from heat recovery in the accounting of total energy use. Heat can be recovered either in the production process, such as when a material is cooled, or through incineration. The Tetrapak study shows that if heat recovery is omitted Tetrapak and the 10-trip refillable bottle use almost equal amounts of energy. However if heat recovery is included in the analysis, the Tetrapak carton uses about 20% less energy than the glass system (Lundholm; Sundstrom, 1985).

As for the degree of recycling consideration, potential and actual levels of heat recovery must be maintained separately.

Weighting the data

The literature review identified three weighting schemes which have been used: MRI weighted the impact data according to impact category, with energy use receiving the highest weight, followed by atmospheric and waterborne emissions, followed by water use, raw materials consumption and solid waste output (Hunt; Welch, 1974); the Franklin study weighted impact data according to the market share of each material studied (Sellers, V.R.; Sellers, J.D., 1989); Wood determined atmospheric and water emissions through an undefined material weighting scheme (Wood, 1975).

A formal process for determining social values leading to weights on various types of environmental impacts should be established.

4.2 Implications for Canada

The issues raised above indicate that existing data are not sufficient for a proper environmental life cycle analysis of packaging materials in Canada. A scope and methodology must be developed so that selection and monitoring of the production plants and disposal technologies will be current and consistent. Otherwise a realistic comparison of the impacts of the various types of packaging cannot be achieved, and specific proposals for design modifications or material type switches cannot be assessed.

5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Reducing packaging does not necessarily reduce environmental stress

The reason for reducing the amount of packaging being disposed of is to decrease environmental impacts. Each of the specific decisions taken to reduce packaging must be scrutinized with respect to this objective. There is no point in reducing packaging if it does not decrease environmental stress.

Reducing the amount of packaging may or may not contribute to environmental improvement. It all depends upon how it is done. Increasing toxic pollution to produce a lightweight package to replace a heavier paper one is probably not a net environmental gain, even though it leads to a reduction in the quantity of waste being disposed.

The waste management hierarchy, which favours reduction, reuse and recycling over recovery and disposal is only a rough guide to environmental preferences. Whether the hierarchy is applicable in particular instances is only revealed through analysis of the environmental consequences.

5.1.2 To be credible and effective, the Protocol should be demonstrably linked to environmental gains

Few of the packaging reduction initiatives will be achieved painlessly. The protocol will be pressing stakeholders to undertake activities in which they would not otherwise willingly engage. To be effective, therefore, the protocol must be infused with the credibility which comes with the clear linkage to environmental objectives.

This was clearly recognized in the U.S. Northeast. CONEG advocated the establishment of a Council, the primary purpose of which is to "provide a publicly credible and accountable basis for industry to undertake a continuing process of source reduction" (as cited in MacLaren Engineers, 1989:5-7).

Without such a clearly articulated basis, neither the voluntary action which comes with consensus, nor the political support essential for effective regulation, will be forthcoming. The concern with reduction "for its own sake" driven by the political difficulties of siting new landfills does not of itself provide a credible basis.

There must be a clear demonstrable link between proposed reduction activities and environmental gains.

5.1.3 Techniques for assessing the environmental effects over the lifetime of a package are partly developed

Numerous studies of specific packaging systems have been undertaken, and there is some commonality among them about the techniques required to assess resource and energy use over the lifetime of a product. However, most of these studies were done in the 1970s and the focus was energy use. Where environmental effects are considered, many of the types of effects considered significant were not recognized at the time the studies were done, and are thus not addressed.

Several studies are under way in the United States, but only limited information is available about these studies. (See entries for Energy Systems Research Group and The Battelle Institute in Appendix B.)

5.1.4 Many of the decisions that will need to be made about packaging systems are not technical decisions, but require the expression of social values

Often gains in one environmental category are obtained at the expense of other kinds of environmental impacts. For example, the release of CFCs into the atmosphere and the disposal of used boxboard into a secure landfill are both environmental impacts associated with packaging disposal; reducing CFCs may increase boxboard disposal and the total mass of packaging being disposed. Meeting the objective of reducing environmental effects requires that the range of impacts to be considered and their relative importance be stated. The selection of impacts to consider, and the expression of importance is primarily an expression of social values, not something that can be done on the basis of a technical assessment of environmental impact.

5.1.5 A full life–cycle analysis of a package is complicated, and could not practically be undertaken by every packager

Setting aside the sometimes thorny methodological issues, and the divergence of views on appropriate social values, a full life-cycle analysis requires extensive data about the manufacturing, use, recycling and disposal processes for each alternative package. Most packagers will not have direct access to all these data, nor the means to assimilate and analyze them.

5.2 Recommendations

5.2.1 The Protocol should clearly indicate that the priority of the National Packaging Policy is to reduce environmental stress, not just to reduce the waste going to disposal

The Protocol should be explicit about its objectives. Waste quantity reductions will not always decrease environmental stress. Some efforts to reduce environmental stress may have no effect on quantities of packaging going to disposal—they may even increase the amount disposed of.

For example, CONEG has identified the removal of toxics from packaging as a primary objective. This will have little or no effect on waste quantities, yet a clear benefit for the environment; a benefit that would be lost if the focus is only on reducing the mass of packaging going to disposal.

5.2.2 A commitment to undertake and act upon life–cycle analyses of packaging systems should play a central role in the Protocol

The Protocol should reflect the importance of the life-cycle analyses. This would take the form of:

- ensuring an environmental profile is prepared for any major modifications proposed to the package system (e.g. material substitution or prohibition)
- ensuring that the audited results play a role in the decisions that are made, i.e. that there is a process for ensuring that the environmental preferences identified are acted upon.

This will require that specific means be developed to decide how to balance competing demands for packaging cost reductions and packaging environmental effects.

5.2.3 Techniques for undertaking life–cycle analyses should be developed

The techniques used in studies undertaken to date need to be refined, both to ensure that they are comprehensive and credible, applicable to the Canadian context, and are capable of being applied to a variety of packaging systems. Among the issues that will need to be addressed are:

- how to deal with electricity
- how to deal with recycling potential compared to actual recycling
- how to deal with circumstances that vary with geography, such as the availability of recycling programs or markets in some but not all locations, or the different mix of electricity generation sources in different parts of Canada
- the boundaries for the analysis
- the approach towards environmental effects that take place outside Canada's borders, related to Canadian packaging
- updating procedures.

In addition to the technique itself, many of the data going into the analysis will need to be standardized to ensure symmetrical and meaningful evaluations are undertaken.

There are several actions which could assist in the development of these techniques, including:

- convening an international conference on environmental life cycle analysis methodologies
- funding pilot studies to explore new techniques, or to explore particular packaging options.

5.2.4 A publicly credible and accountable system for assigning priorities among various environmental effects should be established

Consensus is difficult to achieve with so many interests directly and potentially negatively affected. Consensus items are not necessarily those of greatest benefit to the environment.

Just as CONEG advocated the establishment of a Council, the primary purpose of which is to "provide a publicly credible and accountable basis for industry to undertake a continuing process of source reduction", Canada needs to assign responsibility for:

- determining which environmental effects will be included in the life cycle analyses
- developing the basis for ranking impacts and making trade-offs within the techniques developed for assessing environmental effects over the life-cycle of a package.

Given that these issues require the expression of social values, reaching decisions on these issues should be done only after extensive consultation and debate among the widest possible group of potential stakeholders, and the body reaching a conclusion should be seen as one which is impartial, reasonable, responsive and responsible.

In addition, this body, or a multi-stakeholders task force, could also encourage ongoing national discussions on specific packaging issues, such as:

- the advisability of recycling as an option
- major issues relating to "key switches" from one packaging system to another
- regional variation in objectives, targets and policies for reducing packaging.

5.2.5 A means of simplifying the key components of environmental life–cycle analyses needs to be found to ensure widespread usefulness

Given the enormous range of packaging options in use in Canada, and the number of small packagers, it will be essential to find a means of simplifying the key components of an environmental life–cycle analysis into something which can easily and quickly applied. Possible means for achieving this include:

- development of standard, generic data. For example, all users of glass could be given all the upstream environmental effects of glass, and would only need to add the effects of their own processes.

- development of computerized software for undertaking environmental life-cycle analysis. This software should be simple to use, while ensuring comprehensivity, consistency and clarity[4].

- drawing of generalized, but still credible conclusions from the pilot studies. Pilot studies might make clear either the packaging options which are preferable under a prescribed set of conditions, or which options can be quickly dismissed from further consideration. For example, pilot studies might demonstrate cardboard boxes for cereal are always "better" than the alternatives, and that detailed studies are not required for each location, cereal type, or container size. Even where one option does not always emerge as always preferable, it may be possible to eliminate some options and allow detailed analysis to focus on a smaller number of options.

Ideally, these could be incorporated into an easy-to-follow guide that a packager could use to evaluate his packaging options from an environmental perspective. Obviously, if the guide is to be credible, it will need to be based on the more detailed methodologies and data discussed above.

4The Battelle Institute is developing software that moves in this direction.

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Appendix A Example analysis of impacts for one tonne of steel cans

Attached are five tables which present resource inputs, and outputs of solid waste, air emissions, and liquid effluents for manufacturing one tonne of steel cans.

The data were assembled by Hunt (1974) for the United States, and many of the values will be different in Canada today. However, they indicate some of the points being made in this report:

- a broad range of environmental effects should be considered
- consideration should be made of each process in the manufacturing and use sequence

Although the range of inputs and outputs considered is extensive, it reflects environmental concerns of the sixties and seventies, and ignores many current environmental concerns, such as emissions of greenhouse gases, and ozone depleting substances.

Table A-1
Input requirements for one tonne of steel cans

INPUTS:	Units	Iron ore mining	Lime-stone mining	Coal mining	Lime manu-facturing	Oxygen manu-facturing	External scrap	Clinker manu-facturing	Steel strip	Can fabrica-tion	Filling	Paper packaging	Plastic packaging	Trans-portation (all pro-cesses)	Disposal
wood fibre	kg											20.35			
limestone	kg				125.97			80.48	343.94						
iron ore	kg							283.44	1291.21						
salt	kg														
glass sand	kg														
natural soda ash	kg														
feldspar	kg														
bauxite ore	kg														
material process	kg							13.04	58.65	24.51	0.02	0.22	0.68		
process energy	GJ	0.69	0.02	0.15	0.33	0.69	0.30	10.20	42.47	5.94	2.65	0.82	0.92		
transport energy	GJ	0.11	0.01	0.05	0.00	0.01		0.21	0.73		0.32	0.01		1.70	0.14
water volume	L	14.96	0.17	0.23	0.10	2.06	0.04	54.07	218.88	1.92	0.37	3.61	0.23	0.01	
energy value of material resource	GJ							0.17					0.91		

Source: Hunt, Franklin, *et al*, 1974.
Notes: 1. Disposal includes both landfilling and recycling
2. Blank cells were reported as having a value of zero
3. Cells showing zero values are actually greater than zero, but less than the level of precision indicated.

Table A-2
Solid waste generated from manufacturing and use of one tonne of steel cans

SOLID WASTE:	Units	Iron ore mining	Lime-stone mining	Coal mining	Lime manu-factur ing	Oxyge n manu-factur-ing	Extern-al scrap	Closure manu-facturing	Steel strip	Can fabrica-tion	Filling	Paper packa ging	Plasti c packa ging	Tran s-port ation (all pro-cesses)	Dis-posal
process waste	kg				11.49			79.42	329.98	23.57	25.49	1.13	0.08		
fuel combustion	kg	0.37	0.01	0.17	0.22	0.59	0.19	1.87	6.00	3.95	1.15	1.57	0.50	0.16	0.02
mining	kg	1970.60	0.04	170.72	1.15	1.61	0.04	1034.78	16.54	10.66	4.65	0.50	1.01		
post-consumer solid waste	m^3														0.17

Source: Hunt, Franklin, *et al*, 1974.
Notes: 1. Disposal includes both landfilling and recycling
2. Blank cells were reported as having a value of zero
3. Cells showing zero values are actually greater than zero, but less than the level of precision indicated.

Table A-3
Atmospheric emissions generated from manufacturing and use of one tonne of steel cans

ATMOSPHERIC EMISSIONS	Units	Iron ore mining	Lime-stone mining	Coal mining	Lime manu-facturing	Oxygen manu-facturing	External scrap	Closure manu-facturing	Steel strip	Can fabrica-tion	Filling	Paper packaging	Plastic packaging	Trans-portation (all pro-cesses)	Disposal
particulates	kg	5.18	2.33	1.80	1.20	0.13	0.00	5.69	12.40	0.86	0.58	0.72	0.11	0.11	0.01
nitrogen oxides	kg	0.29	0.02	0.02	0.10	0.26	0.10	2.10	5.47	2.05	1.25	0.29	1.05	1.36	0.06
hydrocarbons	kg	0.23	0.01	0.35	0.07	0.16	0.07	5.51	4.70	12.94	0.83	0.12	1.09	0.49	0.07
sulphur oxides	kg	0.41	0.01	1.16	0.28	0.56	0.20	3.47	12.58	3.71	1.68	0.50	0.49	0.72	0.02
carbon monoxide	kg	0.08	0.02	2.02	0.03	0.06	0.01	0.94	1.22	0.30	0.74	0.11	0.44	1.00	0.50
aldehydes	kg	0.00		0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.01	0.00	0.00	0.05	0.00
other organics	kg	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.01	0.02	0.00	0.00	0.00	0.03
odorous sulphur	kg							0.01	0.50						
ammonia	kg							0.52	2.36		0.00				
hydrogen fluoride	kg														
lead	kg								0.00		0.00			0.00	0.00
mercury	kg														
chlorine	kg														

Source: Hunt, Franklin, *et al*, 1974.
Notes: 1. Disposal includes both landfilling and recycling
2. Blank cells were reported as having a value of zero
3. Cells showing zero values are actually greater than zero, but less than the level of precision indicated.

Table A-4
Waterborne emissions from manufacturing and use of one tonne of steel cans

WATERBORNE EMISSIONS	Units	Iron ore mining	Lime-stone mining	Coal mining	Lime manu-facturing	Oxygen manu-facturing	External scrap	Closure manu-facturing	Steel strip	Can fabrica-tion	Filling	Paper packaging	Plastic packaging	Trans-portation (all pro-cesses)	Disposal
fluorides	kg														
dissolved solids	kg	0.06	0.00	0.01	0.01	0.03	0.02	0.39	1.28	0.28	0.31	0.06	0.11	0.35	0.03
BOD	kg							0.00	0.00		0.00	0.05	0.11	0.00	
Phenol	kg														
sulphides	kg							0.00	0.00		0.00			0.00	
oil	kg							0.15	0.47		0.00		0.05	0.00	
COD	kg	0.00						0.00	0.01	0.00	0.00	0.00	0.10	0.00	0.00
suspended solids	kg							0.52	2.36	0.00	0.00	0.34		0.00	
acid	kg	0.02	0.00	1.80	0.01	0.03	0.01	0.50	2.21	0.21	0.06	0.01	0.03	0.00	
metal ions	kg	0.00		0.45	0.00	0.01	0.00	0.23	0.55	0.05	0.02	0.00	0.01		
cyanide	kg														
chromium	kg														
iron	kg														
aluminum	kg														
nickel	kg														
mercury	kg														
lead	kg														

Source: Hunt, Franklin, *et al*, 1974.

Table A-5
Summary of inputs and outputs from the manufacturing and use of one tonne of steel cans

SUMMARY OF ENVIRONMENTAL IMPACTS	Units	Iron ore mining	Lime-stone mining	Coal mining	Lime manu-facturing	Oxygen manu-facturing	External scrap	Clearon manu-facturing	Steel strip	Can fabri cation	Filling	Paper package	Plastic package	Transport (all processes)	Disposal
raw materials	kg				125.97			376.96	1573.81	24.51	0.02	20.57	0.68		
energy	GJ	0.80	0.03	0.20	0.33	0.70	0.30	10.59	43.20	5.94	3.17	0.82	1.83	1.70	0.14
water	L	14.96	0.17	0.23	0.10	2.66	0.04	54.07	218.88	1.92	0.37	3.61	0.23	0.01	
industrial solid waste	m^3	1970.97	0.05	170.89	12.87	2.21	0.33	1116.07	352.52	38.18	31.30	3.19	1.59	0.16	0.02
air emissions	kg	6.19	2.39	5.35	1.68	1.18	0.39	18.25	39.20	19.87	5.12	1.74	3.18	3.71	0.70
waterborne wastes	kg	0.08	0.00	2.26	0.03	0.07	0.04	1.79	6.89	0.54	0.39	0.56	0.41	0.56	0.03
post-consumer solid waste	m^3														0.17

Source: Hunt, Franklin, *et al*, 1974.
Notes: 1. Disposal includes both landfilling and recycling
2. Blank cells were reported as having a value of zero
3. Cells showing zero values are actually greater than zero, but less than the level of precision indicated.

Appendix B Review of literature on the environmental life cycle of packaging

Hunt, H.G.; R.O. Welch
Resource and Environmental Profile Analysis of Plastics and Non-plastics Containers
Midwest Research Institute
Prepared for The Society of the Plastics Industry, Inc. 1974

This study compares plastic packaging products to commonly used non-plastic substitutes. The comparisons include:

Polyvinyl chloride (PVC) vs. glass bottles
High-density polyethylene (HDPE) jugs vs. paper milk cartons
Low-density polyethylene (LDPE) vs. paper shopping bags
Acrylonitrile-butadiene-styrene (ABS) vs. aluminum food tubs
High-impact polystyrene (HIPS) vs. paper vending cups
High-density polyethylene (HDPE) vs. steel containers
Polystyrene foam vs. pulp meat trays.

The Midwest Research Institute included energy use, raw material consumption, water consumption, industrial solid waste output, air and water emissions, and post-consumer solid waste output in its analysis.

The plastic option was found to require less energy or material inputs and to produce less contaminant output than the non-plastic substitutes with these exceptions; paper milk containers, cardboard vending cups and pulp meat trays use less energy than their plastic equivalents; paper vending cups and pulp meat trays produce less atmospheric emissions; aluminum food tubs and steel containers produce smaller amounts of post-consumer solid wastes.

Unfortunately, many important assumptions are not identified in the summary document. For example, it is not clear whether the glass used in the analysis was one-way non-refillable glass or refillable, or whether any of the products included feedstocks made of post-consumer materials. The technical report is not available.

Franklin Associates
Comparative Energy and Environmental Impacts for Soft Drink Delivery Systems
Prepared for : The National Association for Plastic Container Recovery (NAPCOR) 1989[5]

Unlike most environmental life cycle analyses which determine the net impact of each material on the environment, the objective of this study is to find the proportion of the total environmental impacts which can be attributed to each material. To achieve this goal the impacts of each container type are weighted by the market share of the container and then compared.

The impacts from the production of four sizes of PET bottles, three sizes of non-refillable glass bottles, a refillable glass bottle and an aluminum can are monitored. The impact data are aggregated by material type — glass, PET, and aluminum — and compared.

The difference in the ranking of individual containers and containers aggregated by material highlights the possibility of misinterpreting Franklin's results. The weighting scheme used by Franklin better reflects the market share of a material than it does the environmental impacts of a material; data weighted by the current market shares are not useful for determining the optimal combination of containers.

The aggregated results show PET to be the material which uses the least energy, releases the lowest amount of air and waterborne emissions, and the least solid waste by weight. However when individual containers are compared the refillable bottle is found to be the lowest user of energy, and to produce less atmospheric emissions of any of the nine containers studied; aluminum is found to produce the least post-consumer solid waste by volume.

The study also calculates the effects of the production of each material at five rates of recycling — 0%, 25%, 50%, 75%, and 100%. Increasing the rate of recycling changes the net environmental impact of each material, however it does not significantly affect the relative ranking of materials.

5 This is the second Franklin report on this topic. The first was recalled because calculations for the energy and material consumption of glass were based upon the heavier refillable bottles, although non refillable bottles assumed a large share of the market.

Lundholm, M.P.; G. Sundstrom
Resource and Environmental Impact of Tetra Brik Aseptic Carton and of Refillable and Non Refillable Glass Bottles.
1985

This study does a life cycle comparison of the energy and environmental costs of the Tetrapak, refillable glass bottles, and non-refillable glass bottles, based on packages marketed in Germany.

Tetrapak is found to be superior in almost all impact categories, however the study assumes no recycling of the glass containers. As a result of this omission savings in raw materials and energy used in the production of glass from cullet as well as any reduction in contaminant emissions are not accounted for in the analysis.

Hunt, R.G.; W.E. Franklin; R.O. Welch; J.A. Cross; A.E. Woodall
Resource and Environmental Profile Analysis of 9 Beverage Container Alternatives
Midwest Research Institute
Prepared for the United States Environmental Protection Agency
1974

This study, commissioned by the EPA, provides a cradle to grave analysis of soft drink and beer containers made of glass, ABS plastic, steel and aluminum. A limited analysis is provided for corrugated cardboard and kraft paperboard carrying containers.

MRI provides a detailed description of materials and energy use, waterborne and atmospheric emissions and solid waste production for each stage in the manufacturing process. Unlike the MRI study done for the Society of the Plastics Industry this study includes data for glass, aluminum and steel at various rates of recycling. The addition of recycling data changes the results of the materials comparisons dramatically. For example, whereas the MRI study for the plastics association shows plastic packaging to be superior to glass in terms of energy use, the MRI study for the EPA shows refillable bottles to be superior to all other packaging types.

Of all the studies reviewed, this study offers the most complete life cycle description of different packaging types. Though the results are dated, and analysis of some pollutants such as CO_2 are not included, the study provides a good framework for future analysis.

Brown, C.K.; F.J. Hopton; R.G.W. Laughlin; S.E. Sax
Energy Analysis of Resource Recovery Options
Ontario Research Foundation
1976

This report reviews the energy used in the production of glass, steel, LOPAC® plastic and aluminum. This is a material analysis rather than a study of container systems.

The objective of this study was to show, per tonne of material, the energy savings achieved by recycling. The percentage of secondary materials used in the packaging product was based upon what was technically feasible for each material at the time of research. The recycling of aluminum resulted in the greatest energy savings, followed by LOPAC®, glass and steel.

This study assumes a system boundary of Ontario, although some adjustments have been made to include the energy use of major processes taking place outside of Ontario.

Wood, John David
Packaging and the Environment for Environmentalists Concerned with Packaging, and for Packagers Concerned with the Environment
Pollution Probe
1975

J. David Wood has developed two equations for describing the environmental impacts of a packaging material — one to determine energy use, and the other quantifying wastes and emissions.

The equations are flexible in that they account for changes in the relative proportions of the 3Rs and can be used to compare any packaging type.

The units used to quantify wastes and emissions are dimensionless and therefore can be easily weighted to reflect the relative importance of each type of impact, however no rating system is suggested.

The emissions component relies on (arbitrarily derived) multipliers to represent toxic emissions to water and air. The lack of precision casts doubt on the validity of the results. The model has never been applied.

Berry, Stephen R. and Hiro Makino
Energy Thrift in Packaging and Marketing
Technology Review 76(4)
1974

This study documents the energy required to produce the following container systems: steel and aluminum soft drink cans, glass milk bottles, plastic milk pouches and cartons of milk. The study includes the energy requirements for the production of 1 ton of kraft paper and corrugated cardboard.

No other environmental impacts resulting from the production of packaging materials are assessed.

Energy Systems Research Group
Assessment of the Economic and Environmental Impacts of the Production and Disposal of Packaging and of Public Policy Measures to Alter the Mix
Prepared for: United States Environmental Protection Agency and the Council for State Governments (in progress)

This is a two year study documenting the life cycle of packaging materials. Results from this study are unavailable.

The Battelle Institute,
Columbus, Ohio
(Source: phone conversation with Bruce Vigon, Senior Research Scientist, Business Manager, Environmentally Compatible Products)

The Battelle Institute is currently developing a software package to assess the environmental impacts of the various packaging types and disposal methods.

There are four components to the software:

1. Detailed compositional analysis of the packaging (This is a material component analysis, energy consumption is not yet included in the analysis although it may be added.)

2. Allocation of components to fate pathways (either landfill or incineration)

3. Impacts of each fate
   For example, the quantity and quality of leachate for each of a number of geographic regions in the U.S.; the composition of stack gases and ash resulting from the incineration of each of the material components.

4. Substitution analysis
   There are two parts to this component.

   In the first part impacts (as per component 3) of alternate packaging systems such as refilling or recycling are determined.

   In the second part these impacts are weighted according to environmental and performance criteria. The environmental criteria are degradability, mobility (e.g. in leachate), toxicity, and recyclability. The performance criteria include cost, applicability to existing manufacturing processes, suitability for packaging application and consumer acceptance. These criteria have been used in other risk assessment studies done by the Institute and assumes that they reflect public perceptions.

The study is being sponsored by product manufacturers. Although it is being applied to a limited set of packaging products Bruce Vigon of the Battelle Institute states that it is still "in an evolutionary phase".